A STUDY OF THE PROPERTIES OF WHEAT FLOUR AS PRODUCED BY DIFFERENT MILLING SYSTEMS

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SOME COMPARISONS BETWEEN COMMERCIALLY AND EXPERIMENTALLY MILLED FLOURS[1]

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INTRODUCTION

Wheat flour, as a finished product, ready for the baker, is the result of a long succession of processes—biological, mechanical, and chemical—all of which admit the play of almost innumerable variables. It has been the aim of the investigator interested in flour problems to control, counteract, take advantage of, or evaluate the effects of many of these variables, working toward the production of a suitable product for the making of bread.

Bailey (1925) stated that, "Properties of flour must be considered in their relation to: (first) the raw material from which it is manufactured, or wheat; (second) the process of manufacture, or milling; (third) its adaptability to the principal use to which flour is put, or baking." The first is undoubtedly the most important consideration at this time, and the plant breeder, the agronomist, and the plant pathologist are devoting their energies to the problem of improving the quality of the wheat that is grown, while the grain inspectors and the wheat blenders, as well as the cereal chemists, are devoting their efforts to evaluating the wheat which is marketed, so as to produce the highest possible quality of flour.

The adaptability of flour to baking has been subjected most thoroughly to laboratory investigation. The research along this line has been in the direction of finding the shortest, simplest, and most reliable method of evaluating the baking properties of flour without recourse to the rather lengthy and complicated baking test.

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It is well known to the miller that variations in the milling procedure will produce variations in the properties of the flour, but few quantitative data are available as to the exact nature of these variations.

The plant breeder, in an effort to improve the milling qualities of wheat through selection and breeding practices, can obtain final results in terms of baked bread only through the production of samples of sufficient size to mill into flour. The use of the laboratory mill has greatly reduced the size of sample necessary to produce a workable quantity of flour. Of necessity the milling procedure with a small mill must be quite different from that of the commercial mill.

Classification of the middlings is not attempted to the same degree as in commercial milling. No purification of these middlings is ordinarily provided. It is also probable that the control of pressures on the rolls in the reduction of middlings is less precise and liable to greater variations. A tendency to bolt the ground middlings more extensively is also frequently observed in the ordinary operation of the laboratory mill.

The question arises at once as to the effect of this modified milling treatment on the flour produced, and the advisability of using laboratory data based upon studies of such flour to prognosticate the properties of flour commercially milled from the same wheat. The same reasoning applies to the grain merchant's and miller's practice of milling samples from large shipments to gain advance information concerning the desirability of the wheat in question.

The present investigation was undertaken with these considerations in mind.

Historical

In view of the very comprehensive review of the literature on flour and its properties as related to wheat, milling, and baking, recently compiled by Bailey (1925) and the reviews of the papers on more specialized topics by other authors, no attempt will be made to present here a complete historical review of the subject. Sharp and Gortner (1923) thoroughly reviewed the literature dealing with flour strength. Rumsey (1922) discussed the historical aspects of enzyme phenomena in relation to baking strength.

The following discussion includes only those papers having a direct bearing on the problem at hand.

The Experimental Mill.—The laboratory size of roller flour mill was used by Hays and Boss (1899) in connection with wheat variety and breeding studies. This was only fifteen years after the beginning of the new era in roller milling (Edgar, 1912), and early in the present period of researches on flour.

Total Protein.—The use of the total crude protein as a measure of flour strength has been the subject of considerable controversy. Thomas (1917), in a study of the comparison of total protein content with loaf volume, showed that "high crude-protein content as a rule is accompanied by high strength, but the relation between these two factors varies with the different classes of wheat and extremely high crude-protein content is sometimes accompanied by a decrease in baking strength." Zinn (1923) calculated coefficients of correlation between loaf volume and protein content of both wheat and flour. Values of $r = +0.1827 \pm 0.0459$ were obtained for Minnesota commercial wheat varieties; $r = +0.4621 \pm 0.1011$ for Montana spring wheat varieties. Total protein of flours from Minnesota commercial wheats and from pure-strain wheats correlated with loaf volume gave coefficients of $r = +0.2586 \pm 0.0442$ and $r = +0.5469 \pm 0.0689$, respectively.

Mangels and Sanderson (1925) studied three crops of North Dakota wheats, obtaining in all cases significant positive correlations between loaf volume and total protein content of the wheat.

Nebraska flours reported by Blish and Sandstedt (1925) showed a correlation coefficient of $r = +0.304 \pm 0.058$ between loaf volume and protein content of the wheat.

Mangels (1926) computed coefficients of correlation between loaf volume and protein content of wheats for several individual years and obtained positive correlations in eight out of eleven cases.

Bailey (1924), and Bailey and Sherwood (1926) reported significant positive correlations from a large number of comparisons of protein content of straight grade flours and the loaf volume of loaves baked therefrom. In the latter paper the increase in loaf volume per increment of protein, at various protein levels, was computed.

Grewe and Bailey (1927), in comparing protein content of both hard and soft wheat flours with loaf volume, obtained the coefficient of $r = +0.678 \pm 0.091$.

Diastatic Activity.—The term diastase as applied to the starch-splitting enzyme of malt was first proposed by Payen and Persoz

(1833). Wood (1907) was apparently the first to recognize the importance of the sugar formed from starch hydrolysis in the nutrition of the yeast in a fermenting dough.

Rumsey (1922) after developing a reliable method for the quantitative determination of diastatic or saccharogenic (Bailey, 1925) action of wheat flour, investigated the relation of this property to baking strength. It was found that flours from various sources differed markedly with respect to their starch-splitting power, and other factors being equal, the differences were always reflected in loaf volume. In the fourteen flours examined by Rumsey, variations of 900% in diastatic power were encountered. The influence of time, temperature, and H-ion concentration on the activity of diastase was also studied and the optimum conditions defined. Olsen and Fine (1924) have recently clarified the question of the temperature and H-ion relationship in determining optimum conditions for diastatic action. The optimum pH for the action of malt diastase was found to change from pH 4.3 to pH 6.0 when the temperature was raised from 25° to 69°C. This is in good agreement with the earlier work of Rumsey who found at 27°C. that pH 4.7-5.0 was optimum for the action of flour diastase.

Sherwood and Bailey (1926) determined the effects of adding sprouted wheat to normal wheat to increase the saccharogenic properties of the flour milled therefrom. When two per cent of sprouted kernels were added to wheat which yielded flour having an initial diastatic value of 126 Rumsey units, the diastatic value increased to 204 Rumsey units, the loaf volume was increased 5% and other properties of the bread were improved. Sherwood and Bailey defended Rumsey's method against the criticism of Sørensen, contending that it, after all, most nearly simulates actual dough fermentation conditions.

Sørensen (1924) made the criticism that Rumsey's method did not compare different flours at the same H-ion concentration. It was suggested that after a buffer curve had been determined for a given flour, the diastatic activity should be determined at three different pH values. In this way a curve could be constructed which would be more or less characteristic for the flour and directly comparable with similar curves for other flours.

Following this suggestion, Bailey and Grewe (1927a) determined the diastatic activity of seventeen flours at the natural H-ion concentration of the flour and water mixtures, and at pH 5.0. The rather surprising results showed that those flours with highest

initial diastatic activity increased at a greater rate with changing H-ion concentration than did those with a low initial saccharogenic activity.

Sherwood (1926) reported that the diastatic activity of wheat flour is influenced by grinding. Middlings stocks and flours were tested before and after grinding. Part of the third reduction stock which passed through a 50 GG and over a 72 GG showed a diastatic power (Rumsey's method) of 53 units before regrinding and 103 units after regrinding. Another portion of the third reduction stock which passed through a 50 and a 72 GG, but over a 10 XX, showed 40 units before and 73 units after regrinding. The stocks which tailed off the 10 XX in the fourth reduction showed 60 units and after regrinding 98 units. This appears to be due largely to reduction in the size of particles.

Investigations of Mill Streams.—Richardson (1884) published some of the earliest data available on the composition of mill streams and finished flours from several sections of the United States. His very extensive series of analyses were reported as to: moisture, ash, oil, carbohydrate, fiber, albuminoid nitrogen, phosphoric acid and gluten content. Baking tests were likewise reported; the yield of bread from a given weight of flour was given the most consideration in the analysis of the results.

Bailey (1925) presented the analyses made by Jacobs of all the mill streams of a certain mill.

Analyses including chemical composition and baking tests on the mill streams of a five-break mill were reported by Swanson, Willard, and Fitz (1915). The results obtained by these workers show clearly the excellent baking qualities possessed by the break flours.

Weaver (1921) examined a series of mill streams with respect to ash, gluten, loaf volume, and color. No relation between ash content and gluten could be distinguished in this study. Weaver also concluded that the condition of the wheat before milling and the subsequent mill manipulation were more responsible for variations in ash content than the original ash content of the wheat.

Hendel and Bailey (1924), using the viscosity test, measured the gluten quality of the various mill streams. Dividing the product of the crude protein content, and gluten quality factor by the product of the loaf volume times a texture factor gave, in most instances, a reasonably constant value. Exceptions were accounted

for either by a low-quality, high-gluten content or abnormal diastatic activity.

In a recent study by Cairns and Bailey (1928) the proteolysis of flour-in-water suspensions of different mill streams was determined. Amino nitrogen of an autolyzed suspension was determined using the Sørensen titration. The breaks and tailings flours showed considerably more proteolysis than the more refined streams. The same samples were also studied with respect to viscosity changes in suspensions after 5 hours digestion. A significant positive correlation between decrease in viscosity and increase in amino nitrogen was computed from these data.

Flour Proteins and the Lyotropic Series.—The lyotropic or Hofmeister (1888) series, showing relative neutral salt effects on colloidal systems, has been the subject of a voluminous literature. The general relations of the phenomena to colloid chemistry have been discussed at length by Bancroft (1918, 1921), Freundlich (1926), Rideal (1926), and Gortner (1929). Loeb (1921, 1922) argued against the existence of lyotropic effect of the various ions on protein systems.

Hoffman and Gortner (1927) were the first to note the differential solubility or peptization of flour proteins in different salt solutions. The method in common usage, using 5% K_2SO_4 or 10% NaCl solutions, tacitly assumed an equal solubility of the "globulin" fraction of wheat flour in these solutions. The final products isolated, using the two solutions mentioned as "solvents," differed greatly as to: amount obtained, chemical constitution as revealed by the Van Slyke method of analysis, and ease of redissolving in the original salt solution. A more extensive investigation was conducted later by Gortner, Hoffman and Sinclair (1928, 1929) in which 12 flours were extracted with 21 different inorganic salt solutions, using 0.5, 1.0, and 2.0 N solutions of most of the salts. The results show a distinct lyotropic series for both anions and cations which, with but few reversals, maintained the usual order within the series. The potassium halide solutions showed the most striking regularity with respect to the peptizing power of the halogen ions. Normal solutions of these salts extracted, on an average, KF 13%, KCl 23%, KBr 37%, and KI 64% of the total protein in the flour. Furthermore it was shown that the concentration of the salt solution had only a small effect, in most cases, on the peptizing action; that H-ion concentration played no part in accounting for the varying amount of protein peptized by the different ions

and, lastly, that no hydrolysis of the protein could be detected. It was concluded, from all of the evidence, that the existence of a wheat-flour globulin, as a distinct entity, was seriously open to question.

A statistical study of the above data made by Gortner (1927) revealed the fact that a significant negative correlation existed between the loaf volume and the percentage of protein extractable with a salt solution. The highest coefficient obtained was $r = -0.925 \pm 0.028$ for the series using normal $MgSO_4$, and the lowest, $r = -0.672 \pm 0.107$, for the normal KI series. Calculation of the correlation coefficient between loaf volume and the extracted protein using 5% K_2SO_4 solution for the flours, studied by Sharp and Gortner (1923), gave essentially the same figure: $r = -0.824 \pm 0.065$. It was suggested that after further verification, this apparently trustworthy relation might be used in the prediction of loaf volume without resorting to the time-consuming baking test.

Experimental

The Problem.—The problem as presented was conducted along two principal lines of investigation:—First, the study and comparison of the properties of wheat flour milled from the same sample of wheat with the commercial size of mill (The Minnesota State Experimental Flour Mill), and with the small experimental flour mill; second, the general study of the various mill streams of the milling system employed at the Minnesota State Experimental Flour Mill.

Published evidence, concerning the assumption that experimentally milled flour is identical with flour commercially milled, is meager and conflicting. Such a direct comparison is, however, a common laboratory and trade practice.

In the general study of the mill streams, special emphasis was given to an investigation of the differential peptization of the proteins of these flours by solutions of magnesium sulfate and the potassium halide salts. It was considered worth while to attempt to confirm the results obtained by Gortner, Hoffman, and Sinclair (1928, 1929), using flours showing more variation in protein content and physical properties.

1. **The Material.—Origin and Description of Wheats.**—The wheats from which the flours used in this investigation were milled were selected for milling tests at the Minnesota State Experimen-

tal Flour Mill. The procedure for the milling tests has been described by Bailey (1923).

No. 387 A hard red spring wheat from Carlos, Minnesota. Grade: No. 1 dark northern spring, 2% dockage, test weight 58.5 pounds per bushel.

No. 392 A hard red spring wheat from Clarkfield, Minnesota. Grade: No. 3 dark northern spring, no dockage, test weight 56.5 pounds per bushel.

No. 401 A hard red spring wheat from Shawmut, Montana. Grade: No. 2 northern spring, 1% dockage, test weight, 62 pounds per bushel.

No. 423 Marquis wheat from Manitoba Experimental Farm, Brandon, Manitoba. Grade: No. 4 northern spring, no dockage.

No. 424 Ceres wheat from Manitoba Experimental Farm, Brandon, Manitoba. Grade: No. 1 northern spring, no dockage.

No. 426 A blend of 55% of a hard red spring wheat from Lindsey, Montana. Grade: No. 1 dark northern spring, 2% dockage, test weight 59 pounds per bushel; 45% of a hard red spring wheat from Butte, North Dakota. Grade: No. 2 dark northern spring, 3% dockage, 2.6% durum; test weight 58.5 pounds per bushel.

2. **The Flour Samples.**—Wheat, and patent and straight-grade flour samples were collected from each of the milling tests at the Minnesota State Experimental Flour Mill. The wheat samples were then milled, using laboratory experimental flour mill producing a 75% patent flour.

The eighteen flours thus obtained, together with a series of samples from seventeen mill streams from the State Experimental Flour Mill, constituted the materials studied in this investigation.

The mill-stream flours were included in this study because they, too, represent flour resulting from different milling treatment and, incidentally, vary considerably in chemical composition and physical properties.

Methods

1. **Experimental Milling.**—Two thousand grams of cleaned wheat was weighed in a tightly covered container. Sufficient water was added to raise the moisture content to 14.5%, the sample thoroughly mixed, and allowed to stand. After 12 hours the wheat was retempered by adding water, until 15.5% of moisture was reached, and again the mixture was allowed to stand for three hours.

In the initial grinding the first and second, third and fourth, and fifth and sixth "breaks" were made, respectively, with the Nos. 16, 20 and 24 corrugated rolls. The bran was collected on a No. 20 wire mesh sieve, the shorts on a No. 30 GG cloth sieve, and the middlings were collected on a No. 12 XX cloth, the flour passing the No. 12 XX comprising part of the clear grade flour. The shorts and bran were passed through the smooth rolls once, and

sifted to reclaim adhering flour, which was added to the clear grade.

Eight reductions of the middlings were carried out, using the smooth rolls. The middlings were purified during the reduction process by passing them successively through No. 50 GG, No. 64 GG, and No. 70 GG cloth sieves, regrinding, each time, the middlings retained on the No. 10 XX sieve. Flour passing the No. 10 XX was combined, re-sifted and reserved as patent flour.

2. **Diastatic Activity.**—The diastatic activity of the laboratory mill patent and the large mill patent and straight-grade flours was determined, using Rumsey's method, as modified slightly by Sherwood and Bailey (1926).

Ten-gram samples were weighed into 200 cc. volumetric flasks and placed in a water bath which was held at a temperature of 27°±0.1°C. After attaining the temperature of the bath, 100 cc. of distilled water, warmed to 27°C., was pipetted into flasks and the flasks rotated to produce a smooth suspension. After digestion for exactly one hour, enzyme action was inhibited and the suspension clarified by the addition of 3 cc. of 15% sodium tungstate and a few drops of concentrated sulfuric acid. The proper acidity for good clarification was attained by adding a slight excess of acid beyond the amount necessary to produce a pink color in the flour suspension, using thymol blue as indicator. After diluting to 200 cc. and shaking, the suspension was centrifuged at high speed for 10 minutes. Fifty cubic centimeter aliquots were then pipetted into 400 cc. beakers and the reducing sugars determined by the Quisumbing and Thomas (1921) modification of the Fehling copper reduction method. With this method the Fehling's solution and sugar mixture is heated for exactly 30 minutes in a water bath at 80°C.

After the reduction period the Cu_2O was collected on asbestos in Gooch crucibles and the copper determined by the volumetric permanganate method. This procedure consists of transferring the asbestos mat and Cu_2O to a beaker and adding 50 cc. of a hot 20% H_2SO_4 solution previously saturated with $Fe_2(SO_4)_3$. The mixture is then titrated, while hot, with a standard solution of $KMnO_4$. The $KMnO_4$ solution used had a Cu equivalent of 10.00 mgm. per cc. The weight of reducing sugars, in terms of maltose, were obtained by consulting the tables published by Quisumbing and Thomas (1921). The blank for the reagents was combined with the blank for the natural reducing sugars in the flour, necessitating

only a single correction to obtain the weight of maltose produced by diastatic action.

In the study of the diastatic activity of the mill stream flours, the method of procedure was essentially the same as that noted above. It seemed desirable, however, to eliminate any variation that might occur due to differences in H-ion concentration of the flour-in-water suspensions. This was accomplished, in most instances, by the addition of 5 cc. of a sodium acetate-acetic acid buffer, having a pH of 5.0. In the case of the lower grade flours with a high natural buffer capacity, a predetermined amount of 0.05 N lactic acid was added to bring the pH of the digestion mixture to approximate pH 5.0.

3. **H-ion Concentration.**—The H-ion concentration of flour-in-water suspensions was determined in all cases by the electrometric method. Five grams of flour was transferred to a centrifuge tube and 50 cc. distilled water added. The tube was stoppered and shaken to produce a uniform suspension. The suspension was shaken at frequent intervals during one hour. At the end of this time the water extract was clarified by centrifuging for 10 minutes. The potentiometric readings were taken as soon as possible, using a Leeds and Northrup precision potentiometer graduated to read directly in pH. The Bailey hydrogen electrode was used, and each determination was duplicated, using two different electrodes.

In determining the pH of the buffered flour-in-water suspensions of the mill-stream flours, 2.5 cc. of the sodium acetate-acetic acid buffer was added and the suspension digested for an hour.

To determine the quantity of 0.05 N lactic acid necessary to produce an acidity of pH 5 in suspensions of some of the low-grade mill streams, a bubbling hydrogen electrode of the Hildebrand type was successfully employed. The 0.05 N lactic acid was added directly to the flour suspension contained in a titration vessel and the potentiometric reading was taken after each addition of acid. Each reading was duplicated, using two different electrodes.

4. **Baking Tests.**—The baking tests were conducted according to the standard 100 gm. flour procedure recently adopted by the Committee on Standardization of the Experimental Baking Test of the American Association of Cereal Chemists (Blish, 1928). The loaf volume was measured, using the measuring device designed by Werner. Each of the 36 flours was baked in duplicate on different days.

5. **Protein Extractions with Salt Solutions.**—The method followed in studying the differential peptization of flour proteins by different salt solutions was essentially the one described by Gortner, Hoffman, and Sinclair (1928). A preliminary study of the relative proportions of the peptizable protein removed by successive extractions on the same sample, showed that the number of extractions per sample might be reduced to one or two. Accordingly, the method adopted involved the use of two successive extractions for each sample.

Six-gram portions of flour were placed in a series of thick-walled, non-lipped centrifuge tubes of 100 cc. capacity. To these was added 50 cc. of the salt solution, and the stoppered tube shaken to suspend the flour in the liquid. The tubes then were placed in a mechanical shaker and shaken for a half hour after which the flour suspensions were centrifuged at high speed for 10 minutes. The clear or slightly opalescent liquids were decanted into 800 cc. Kjeldahl flasks, an additional 50 cc. of salt solution was added to the residue in the centrifuge tubes, the solid mass was loosened and broken up with a stirring rod, and the tubes were again shaken for one-half hour. The solutions from the second extraction were combined with those of the first extraction and the nitrogen determined by the Kjeldahl-Gunning procedure. Each of the determinations was conducted in triplicate, and if there was poor agreement between replicates, the procedure was repeated.

Moisture and total nitrogen determinations were made on the flours, and the protein content (N x 5.7) calculated on a moisture-free basis.

The salt solutions were prepared in all cases from "C. P." grade chemicals and the final solutions standardized. Since Gortner et al, 1928, 1929) found that the effect of concentration on the peptizing power of solutions of many of the salts was small, and the results for 0.5 N concentrations were, in general, representative, a single solution of each salt of 0.5 N concentration was chosen for this work.

The Data

1. **Mill Yields.**—The yields of the different mill products, obtained by grinding each of the wheats in the small experimental flour mill, are shown in Table I. The shorts and bran were combined as total feeds and recorded as the per cent by weight of the original weight of the wheat sample. The weight of the "clear"

TABLE I

SHOWING RESULTS OF MILLING TESTS ON DIFFERENT WHEATS

Wheat Number	Laboratory Mill				Commercial Mill[1, 2]		
	Total Flour	Total Feeds	Total	Yield of 75% patent in gms. from 2000 gms. wheat	Total Flour[3]	Total Feeds	Total Products
	%	%	%		%	%	%
387	66.00	34.00	100.00	960	68.53	33.84	102.37
392	69.50	30.50	100.00	913	69.47	34.10	103.57
401	69.25	30.75	100.00	1009	73.03	27.55	100.58
423	71.00	29.00	100.00	960	73.38	28.05	101.43
424	70.00	30.00	100.00	998	72.25	29.07	101.32
426	71.00	29.00	100.00	935	.....	.....	

[1] Experimental data made available from the records of the Minnesota State Experimental Flour Mill.
[2] All yields calculated to basis of original moisture content of wheat.
[3] Total flour yields all corrected to basis of 13.5% moisture content in flour.

flours, combined with that of the patent, was recorded as total flour.

For purposes of comparison, the mill yields from the same wheats, as obtained from the milling procedure of the Minnesota State Experimental Flour Mill, are likewise shown in Table I. The total flour yield values are recorded as corrected to a uniform 13.5% moisture basis. Since wheat No. 426 for the laboratory milling tests was obtained from a "blended" wheat mixture, no information regarding the yields of milled products from the commercial mill was available.

2. **Saccharogenic Activity of "Commercial" and "Experimental" Mill Flours.**—The results from the determination of saccharogenic activity of the large mill patent and straight-grade and experimental mill patent flours are recorded in Table II. The digestions in each case were carried out at the natural H-ion concentration of the 1 : 10 flour-in-water suspensions. The pH of the individual flour suspensions are shown in the table.

TABLE II

COMPARISON OF SACCHAROGENIC ACTIVITY OF THREE SAMPLES OF WHEAT FLOUR MILLED FROM THE SAME SAMPLE OF WHEAT, AND THE HYDROGEN ION CONCENTRATION OF A 1:10 FLOUR-IN-WATER SUSPENSION

No.	Commercial Mill Patent		Experimental Mill Patent		Commercial Mill Straight-grade	
	pH	Maltose	pH	Maltose	pH	Maltose
		mgm.		mgm.		mgm.
387	6.05	137.3	6.03	52.7	6.12	110.9
392	5.90	112.8	5.83	39.5	5.83	103.4
401	6.00	171.1	5.95	41.4	6.29	163.6
423	6.30	120.4	6.23	33.8	6.37	110.9
424	6.30	146.7	6.14	91.2	6.28	125.1
426	6.03	163.7	6.01	37.6	6.12	149.5

An inspection of Table II reveals the fact that the commercially milled patent flours had, in all cases, a much higher saccharogenic activity than either the straight-grade or the experimentally milled flours. The differences range from only a slight advantage over the straight-grade to values of from 1.5 to over four times the saccharogenic activity of the "experimental" patents. The table shows that only a small part of the variations can be accounted for on the basis of differences in H-ion concentration. It is true that Rumsey (1922) found the saccharogenic activity to change rapidly with changes in H-ion concentration within the range of pH encountered in this study, yet the variations in saccharogenic activity which were found are of sufficient magnitude to place them outside the realm of influence of this factor.

The other alternative is to explain the wide difference in saccharogenic activity on the basis of differences in granulation or fineness of division of the flour particles. Alsberg and Griffing (1925), and Alsberg (1927) indicate that this factor is of importance in its bearing on the ease with which diastase may attack the starch granules in flour. Alsberg et al concluded, from a study of the effects of overgrinding on flour, that the increase in saccharogenic activity with increased fineness of granulation was due to two factors. The first, and most important, was the increased ease of dispersion of the starch in cold water, and the second, a mechanical factor, the freeing of the starch granules from the gluten matrix.

A cursory physical examination of the flour milled with the experimental mill convinces one that the degree of subdivision is considerably less than that of the commercially milled flours.

Accordingly, patent flour No. 401 was milled in a porcelain ball mill for varying periods of time and the saccharogenic activity was determined. These data are given in Table III and show that a flour with relatively high initial saccharogenic activity can have its activity materially increased by further milling. This, in gen-

TABLE III

Showing Increase in Saccharogenic Activity of a Flour Due to Grinding in a Ball Mill for Different Periods of Time

Time of Grinding in Ball Mill	Anhydrous Maltose by Diastase per 10 grams Flour	Increase by Milling	Increase Due to Regrinding
Hours	mgm.	mgm.	%
0	171.2	0	
4	182.6	11.4	6.6
8	208.9	37.7	22.0
20	231.4	60.2	35.2

eral, agrees with the results obtained by Alsberg and Griffing (1925) wherein the saccharogenic activity of a flour was increased fourfold by grinding 53 hours in a ball mill.

The variations exhibited between flours of the same class are typical when compared with the data of other workers. Hermano and Rask (1926) have recently published the results of a study of the susceptibility of different wheat starches to hydrolysis by diastase and suggested that individual variations might be traced to differences in geographical origin and climatic environment of the parent wheats.

3. **Saccharogenic Activity of the Mill Streams.**—The results for the saccharogenic activity of the mill-stream flours, together with the pH of the digestion mixtures are given in Table IV.

TABLE IV

Showing Saccharogenic Activity of the Various Mill-Stream Flours at the Same H-ion Concentration

Arbitrary Grade	Mill Stream	Buffered Water Suspension	Anhydrous Maltose from 10 gms. Flour
		pH	mgm.
—	First break	5.11	299.1
+	Second break	5.10	230.5
+	Third break	5.18	186 3
—	Fourth break	5.13	203.2
—	Fifth break	5.17	197.6
++++	First middlings	5.08	264.3
++++	Second middlings	5.06	255.7
++++	Third middlings	5.06	291.6
+++	Fourth middlings	5.06	239.2
++	Fifth middlings	5.06	199.5
+	Sixth middlings	5.06	260.6
+	Sixth middlings tailings	5.06	211.6
—	First tailings	5.02	277.5
—	Second tailings	5.00	294.4
++	Sizings	4.95	354.6
- - -	Bran and shorts duster	5.05	336.7
- - -	Low grade	4.90	306.6

The values recorded are the averages of two or more replicates. The various flours used in this study were assigned arbitrary grades based upon their ash content. The plus signs were used to indicate relative degrees of refinement, and the minus signs the lower grades. In general, the high values for the saccharogenic activity are found in the lower grades of flour. Bailey (1923) reported the per cent of ether extract in the various mill streams of the Minnesota State Experimental Flour Mill, as an index of the germ content of the flour. In the light of these data, the high saccharogenic activity of the low-grade, duster flour, sizings, first

and second tailings, and fourth and fifth "break" flours may be attributed to a relatively high germ content.

4. **Baking Tests on "Commercial" and "Experimental" Flours.** —The complete data obtained from the baking tests on the "commercial" and "experimental" flours are given in Table V. The different values there recorded were obtained from the average of duplicate determinations baked on different days. The mean values for the different types of flour are shown for purposes of general comparison. An inspection of the percentage "absorption" reveals

TABLE V

RECORD OF PROTEIN CONTENT OF FLOURS AND COMPARATIVE BAKING TESTS WITH COMMERCIALLY AND EXPERIMENTALLY MILLED FLOURS

No.	Description	Crude Protein (Moisture-free basis)	Absorption	Volume of loaf	Color Score	Texture	Grain	Crust Color
		%	%	cc.				
387	Pat.	12.37	63	372	98	98.0	96.0	98.5
387	Str.	12.54	63	397	96	99.0	94.5	98.0
387	Exp.	11.86	53	407	98.5	98.0	98.5	98.5
392	Pat.	13.34	64	430	98	97.5	98.5	97.0
392	Str.	14.48	63	450	98	97.5	97.0	97.0
392	Exp.	14.08	53	442	99	97.0	98.0	98.5
401	Pat.	13.22	65	430	100	97.0	99.0	97.5
401	Str.	14.08	68	417	99.5	99.0	99.5	99.0
401	Exp.	12.97	54	402	100.5	97.5	99.0	98.5
423	Pat.	11.91	64	377	98	98.0	98.0	96.5
423	Str.	12.43	65	362	98	98.5	97.0	98.5
423	Exp.	11.86	55	347	98	98.0	98.0	97.5
424	Pat.	12.54	71	362	99	98.0	96.5	98.0
424	Str.	13.17	73	392	98	98.0	95.0	96.5
424	Exp.	12.31	58	360	98	97.0	98.0	99.0
426	Pat.	13.17	63	400	99	97.5	99.0	98.5
426	Str.	13.39	63	400	98	98.0	98.0	98.5
426	Exp.	12.65	56	382	99	98.0	98.5	98.5
	Mean for patent	12.76	65	395.2	98.5	97.6	97.8	97.6
	Mean for Straight grade	13.35	65.8	403.0	97.9	98.8	96.8	97.8
	Mean for Experimental	12.62	54.8	390.0	98.8	97.6	98.3	98.4

Pat. = Patent; Str. = Straight; Exp. = Flour milled on laboratory mill.

the fact that the absorption of the "experimental" patent flours is invariably lower than the corresponding values for the "commercial" flours. The mean values show a difference of approximately ten per cent with respect to this property. No consistent variations were encountered in the loaf volume representing the three flour types. The differences in the mean values probably have no significance in view of the number of observations involved. In view of the personal element involved in the arbitrary assignment of values to the other bread properties, little significance can be

attached to the small differences obtained in the color, texture, grain, and crust color scores. Considering the average values, the "commercial" and "experimental" patents are virtually identical as to color score and texture and differ only slightly in grain and crust color scores. As would be expected, the straight-grade flour is slightly inferior as to color and grain, but superior as to loaf volume and texture, and intermediate in crust color value.

5. **Baking Tests on Mill Streams.**—Table VI shows the results of the experimental tests of the seventeen mill-stream flours. The

TABLE VI

RECORD OF PROTEIN CONTENT OF FLOURS AND COMPARATIVE BAKING TESTS ON SEVENTEEN MILL STREAM FLOURS

Description	Crude Protein (Moisture-free basis)	Absorption	Volume of loaf	Color Score	Texture Score	Grain Score	Crust Color Score
	%	%	cc.				
First break	13.62	61	387	89.0	98.5	97.5	98.5
Second break	13.74	60	372	95.5	99.0	98.5	98.0
Third break	15.79	62	430	93.5	98.0	99.0	97.5
Fourth break	17.50	62	475	90.0	97.0	98.0	97.0
Fifth break	19.55	63	487	87.0	96.0	97.0	97.0
First middlings	13.11	62	347	97.0	98.0	97.5	98.0
Second middlings	12.71	62	390	98.0	98.0	98.0	98.0
Third middlings	12.82	63	385	98.0	98.5	98.5	98.0
Fourth middlings	13.28	63	400	99.5	98.0	99.5	97.0
Fifth middlings	13.28	62	415	99.5	98.0	99.5	97.5
Sixth middlings	13.79	65	432	99.0	97.0	98.5	97.5
Sixth middlings tailings	13.34	64	417	99.0	98.0	99.0	98.0
First tailings	12.54	66	372	96.0	91.0	93.5	98.0
Second tailings	14.02	64	412	94.0	86.0	94.0	98.0
Sizings	12.48	62	380	96.5	98.0	97.0	100.0
Bran and shorts duster	15.39	60	415	82.5	80.0	92.5	97.0
Low grade	22.34	73	310	70.0	70.0	50.0	95.5

values for the loaf volumes are highly variable. It is notable also that many of the flours graded low in Table IV show, in general, the larger loaf volumes. An examination of the color scores, however, serves to point out the inferiority of these flours. The texture, grain, and crust color scores are somewhat less variable in magnitude but are in most cases indicative of flour quality. The absorption values, it should be noted, fall within a relatively narrow range.

6. **Flour Proteins and the Lyotropic Series.**—Gortner, Hoffman, and Sinclair carried out three extractions with fresh portions of the salt solution on each sample. Since this was a rather laborious and time-consuming procedure, a preliminary study was un-

dertaken to ascertain whether a single extraction could be substituted for the triple extraction. Table VII shows the results obtained from the nitrogen determinations on the first extract, on the second plus the third extracts, and on the fourth plus the fifth extracts from the same sample of flour. The results are given for extractions with 0.5N KBr, KCl, and $MgSO_4$ solutions, using three flours which differed somewhat in total nitrogen content.

The first column gives the per cent of total nitrogen for the different flours, and Columns 3, 6, and 9 show the nitrogen in milligrams which was peptized by the successive treatments with salt solutions. Columns 4, 7, and 10 give the percentages of the total nitrogen of the flour peptized in the several fractions. In Columns 5, 8, and 11 are shown the nitrogen found in the extracts expressed in terms of per cent of the total nitrogen which was peptized. Thus, the nitrogen in each fraction is shown in its relation to the total nitrogen of the flour and to the total peptizable nitrogen. If a single extraction were to give the same relative peptization values for different salt solutions as the method employing three extractions, the peptizable nitrogen in the first fraction, expressed either as percentage of total nitrogen or of total peptizable nitrogen, should, using a given salt solution, assume a constant value within the series.

After a consideration of the experimental errors involved, and of the inherent differences between flours encountered by Gortner et al and later in this work, the values obtained show fair agreement.

Because of the variations shown in the preliminary study, it was thought that in subsequent work some of the irregularities might be eliminated by making two extractions on the same sample, at the same time effecting a substantial saving in time over the method as used by Gortner and his co-workers. The percentage error in the nitrogen determination would also be reduced by the addition of the nitrogen peptized by a second treatment of the sample.

The results of the study of the relative amounts of nitrogen peptized from the flours of the seventeen mill streams by two extractions with 0.5 N solutions of KBr, KCl, KF, and $MgSO_4$ have been assembled in Table VIII. It was assumed here that all of the nitrogen was of protein origin, but in the consideration of the data nothing was to be gained by converting it into terms of protein by using the arbitrary conversion factor, 5.7. The nitrogen peptized by the different salt solutions was expressed in each case as the

TABLE VII

SHOWING RELATIVE AMOUNTS OF NITROGEN PEPTIZED BY SUCCESSIVE TREATMENTS WITH 0.5N SOLUTIONS OF KBr, KCl, AND $MgSO_4$

Total Nitrogen in Flour	Description	0.5N KBr			0.5N KCl			0.5N $MgSO_4$		
		Nitrogen Peptized	Per Cent of Total Nitrogen	Per Cent of Total Nitrogen Peptized	Nitrogen Peptized	Per Cent of Total Nitrogen	Per Cent of Total Nitrogen Peptized	Nitrogen Peptized	Per Cent of Total Nitrogen	Per Cent of Total Nitrogen Peptized
%		mgm.			mgm.			mgm.		
1.62	Flour A									
	Extract 1	21.78	25.71	65.17	16.28	19.23	66.12	15.18	17.86	76.09
	Extracts 2 and 3	9.46	11.17	28.31	5.61	6.62	22.79	3.87	4.57	19.40
	Extracts 4 and 5	2.18	2.57	6.52	2.73	3.22	11.09	0.90	1.06	4.51
	Total	33.42	39.46	100.00	24.62	29.07	100.00	19.95	23.56	100.00
2.43	Flour B									
	Extract 1	26.85	21.10	63.58	19.50	15.32	71.30	19.07	15.18	76.38
	Extracts 2 and 3	12.24	9.61	28.98	5.00	3.93	18.28	4.04	3.17	16.16
	Extracts 4 and 5	3.14	2.47	7.43	2.85	2.24	10.42	1.89	1.48	7 56
	Total	42.23	33.17	100.00	27.35	21.48	100.00	25.00	19.63	100.00
2.19	Flour C									
	Extract 1	25.50	22.00	65.02	19.30	16.39	71.35	18.89	16.29	76.97
	Extracts 2 and 3	9.75	8.41	24.86	5.47	4.72	20.19	4.24	3.66	17.28
	Extracts 4 and 5	3.97	3.42	10.12	2.32	2.00	8.56	1.41	1.22	5.75
	Total	39.22	33.83	100.00	27.09	23.37	100.00	24.54	21.17	100.00

TABLE VIII

SHOWING RELATIVE AMOUNTS OF NITROGEN PEPTIZED FROM THE MILL-STREAM FLOURS BY TWO EXTRACTIONS WITH 0.5 N SOLUTIONS OF KBr, KCl, KF, AND $MgSO_4$

No.	Sample	Nitrogen in Flour Moisture-free Basis	Total Nitrogen in Flour Peptized by:			
			0.5 N KBr	0.5 N KCl	0.5 N KF	0.5 N $MgSO_4$
		%	%	%	%	%
1	First break	2.39	27.16	18.97	14.69	18.51
2	Second break	2.41	23.63	17.19	13.41	16.89
3	Third break	2.77	23.45	16.65	12.57	15.83
4	Fourth break	3.07	25.86	19.00	14.00	18.37
5	Fifth break	3.43	28.11	21.69	15.67	20.28
6	First middlings	2.30	26.88	18.70	13.79	17.56
7	Second middlings	2.23	27.18	19.21	14.28	17.95
8	Third middlings	2.25	26.40	18.89	14.06	17.46
9	Fourth middlings	2.33	26.53	18.21	13.64	17.01
10	Fifth middlings	2.33	26.64	19.32	14.06	17.89
11	Sixth middlings	2.42	27.14	19.41	14.54	17.95
12	Sizings	2.19	28.39	20.71	15.52	19.90
13	Sixth middlings tailings	2.34	29.68	21.87	16.28	20.27
14	First tailings	2.20	28.67	23.98	17.67	22.97
15	Second tailings	2.46	36.81	29.21	22.23	28.35
16	Low grade	3.92	34.17	29.93	26.86	28.20
17	Bran and shorts duster	2.70	34.57	27.99	24.08	25.82
	Average		28.31	21.23	16.31	20.07

per cent of the total nitrogen content of the respective flours. The average values for the entire series of flours were calculated and appear in the table.

Discussion of the Data

1. **Saccharogenic Activity.**—From the results of this comparative study of the saccharogenic activity of commercially and experimentally milled flours, it is apparent that flours milled with the laboratory mill do not provide reliable information regarding the saccharogenic properties of commercially milled flours milled from the same wheats. While the present series of data are obviously meager for generalization, this contention is supported by additional data (yet unpublished) collected by one of the authors (Sherwood). The discrepancies which were observed cannot be accounted for on the basis of differences in H-ion concentration. Since the temperature and time of reaction were kept constant, the differences in size of particles remain as the probable principal causal factor. This difference in degree of subdivision is a variable which seemingly has received little consideration by workers in the field and although probably relatively unimportant in the comparative study of "commercial" flours, it should be considered as one of the reaction variables.

Contrary to the results of Rumsey and others the apparent deficiency in saccharogenic activity of the "experimental" flours was not reflected in the loaf volume when the flours were baked. The average loaf volumes for the different flours, shown in Table V, are essentially identical, yet the saccharogenic activity of the "commercial" flours ranged from 1.5 to 4 times that of the "experimental" flours. This lack of correlation between loaf volume and saccharogenic activity may be attributed to two factors: the quantity of sugar added to the dough and the relatively short, *standardized* fermentation period employed in the "small dough" baking test. The quantity of sucrose added in the dough formula evidently was sufficient for the nutrition of the yeast during the fermentation period and did not need to be augmented greatly by sugars formed by starch hydrolysis.

Judging from these results, the basic procedure of the American Association of Cereal Chemists standard baking test, tentatively adopted, fails to distinguish in terms of loaf volume such marked differences in saccharogenic activity, as were represented by the flours used in this study. It is conceivable that a commercial procedure involving a longer fermentation period and less sugar in the formula might give quite different results from those given by the standard baking test.

The American Association of Cereal Chemists has added a modification of the basic procedure providing for longer fermentation periods. This supplementary method has been added since the present study was completed, and it has been suggested that it may be used when it is desirable to determine fermentation tolerance.

Blish, Sandstedt, and Platenius (1929) have shown a significant positive correlation between diastatic activity and crust color, also between residual sugar in the loaf and crust color based on tests with the standard A.A.C.C. baking method. From their results and the data presented here it is quite evident that crust color and not loaf volume should be the criterion of diastatic activity when the A.A.C.C. baking test with fixed fermentation time is used.

If any significance were to be attached to the "absorption" of the flour, the values shown in Table V clearly indicate that the experimentally milled flours do not give a reliable index to absorption of commercially-milled flours.

The saccharogenic activities of the various mill-stream flours determined at a constant H-ion concentration show a considerable range of variation. The results given in Table IV show the effect

of composition and to some extent the effect of mechanical treatment on the saccharogenic activity of the flours. As might be expected the saccharogenic activity is particularly indicative of the germ content of the various streams. This fact has been pointed out many times by other workers.

2. **Baking Tests.**—The only significant difference between the "commercial" and "experimental" flours revealed by the baking test was the consistently lower "absorption" of the "experimental" flours. The experimental flours had a mean absorption approximately 10 per cent below the mean absorption value for the commercial flours.

In view of the consideration at present being given to the relation between total protein content and loaf volume, it seemed desirable to test the relation between these variables in the "commercial" and "experimental" series of flours. Such a relation is best expressed by the coefficient of correlation. Accordingly, the data for protein content and loaf volume as presented in Table V were subjected to a statistical study, using the formula developed by Harris (1910). The coefficient of correlation between loaf volume and protein content was found to be $r = +0.797 \pm 0.041$. This constant which is roughly twenty times its probable error may be considered unquestionably significant. The class averages representing protein content and loaf volume were plotted graphically. The regression line was likewise plotted and showed that in this series of flours the relation between protein content and loaf volume was approximately linear.

From the data for the mill-stream flours in Table VI the correlation coefficients between the same variables were calculated. The coefficient of correlation between protein content and loaf volume was found to be $r = -0.018 \pm 0.164$. It is of interest that this coefficient, when considered with respect to its probable error, is of no significance in expressing a relationship between the variables, if the series of flours comprises different mill streams milled from the same sample of wheat, as contrasted with a high correlation when the same grade of flour is milled from each of several different lots of wheat.

3. **Flour Proteins and the Lyotropic Series.**—The data presented showing the specific ion effect on the peptization of flour proteins confirm in all respects the findings of Gortner, Hoffman, and Sinclair (1928, 1929). From an inspection of Table VII and particularly of Table VIII, it is clear that a definite lyotropic effect

exists within the halogen salt series. Without a single reversal the ion effect may be arranged Br>Cl>F. The relative amounts of nitrogen peptized are less, with the exception of the values for KF, than those reported by Gortner et al. This is probably due in part to the reduction in the number of extractions made on each sample from three to two. It was thought that perhaps the decidedly abnormal values obtained for the second tailings, low-grade, and duster flours were exerting a disproportionate influence on the calculated means for the whole series. Accordingly, the means, standard deviations, and coefficients of variability were calculated for each salt, first with the whole series intact ($N = 17$), and then with the mill-stream flours Nos. 15, 16, and 17 excluded from the series ($N = 14$). The results appear in Table IX.

TABLE IX

THE MEAN, STANDARD DEVIATION FROM THE MEAN, AND VARIABILITY OF THE PERCENTAGES OF TOTAL NITROGEN PEPTIZED BY FOUR SALT SOLUTIONS FROM A SERIES OF MILL-STREAM FLOURS

No. in Series	Constant	KBr	KCl	KF	$MgSO_4$
17	Mean	28.31 ±0.58	21.23 ±0.65	16.31 ±0.65	20.07 ±0.62
17	Standard deviation	3.556037	4.006896	3.991330	3.803029
17	Coefficient of variability	12.56%	18.87%	24.46%	18.95%
14	Mean	26.84 ±0.30	19.56 ±0.34	14.58 ±0.23	18.49 ±0.32
14	Standard deviation	1.665326	1.864945	1.265120	1.755418
14	Coefficient of variability	6.20%	9.54%	8.68%	9.49%

From Table IX it is quite clear that the three abnormal members of the flour series have doubled and, in the case of the KF series, trebled the variability. The standard deviations from the means were likewise reduced approximately one-half by excluding flours Nos. 15, 16, and 17. The table also reveals the fact that the percentages of total nitrogen peptized by 0.5 N KBr solution are less variable than the corresponding values for the other salt solutions.

In Tables VII and VIII the flours with high nitrogen content apparently yield a *relatively* larger peptizable fraction. An attempt was made, therefore, to measure the relation between total nitrogen content and the peptizable fraction. The most desirable means of expressing this relationship seemed to be by calculation of the coefficient of correlation between the nitrogen content and the deviation of the peptized fraction from its probable value. The following formula developed by Harris (1909) was used:

$$r_{px} = \frac{r_{px} - V_p/V_x}{\sqrt{1 - r_{px}^2 + (r_{px} - V_p/V_x)^2}}$$

r_{pz} = the correlation between the nitrogen content and the deviation of the peptized fraction from its probable value where:

$r_{p\pi}$ = the correlation coefficient between total nitrogen content and the amount of nitrogen peptized.

V_p = the coefficient of variability for the total nitrogen content.

V_π = the coefficient of variability for the amount of peptized nitrogen.

The calculated results are found in Table X.

TABLE X

Showing for a Series of Mill-Stream Flours the Correlation Coefficient between the Total Nitrogen Content and the Amount of Nitrogen Peptized, and the Correlation between the Nitrogen Content and the Deviation of the Peptized Fraction From Its Probable Value

0.5 N Salt Solution	$r_{p\pi}$	r_{pz}
KBr	+0.87707	+0.369316
KCl	+0.860561	+0.554965
KF	+0.83854	+0.606362
$MgSO_4$	+0.858840	+0.547994

The calculated coefficients, r_{pz}, show that the influence of the original protein concentration on the relative amounts peptized by the various salt solutions varies in the reverse order of the peptizing effect of the ions. In other words, with the KBr solution the peptized fraction more nearly approaches a constant value irrespective of the protein content of the flour than with any of the other salts used. Whatever the explanation may be for the variations here encountered, the data demonstrate again, in a slightly different manner, the lyotropic effect of the ions in question.

To determine whether the relation between loaf volume and the peptizable protein fraction, recently reported by Gortner (1927), could be demonstrated with the mill-stream flours, the coefficients of correlation between these variables were computed. For the KF series the correlation was $r = -0.317 \pm 0.147$; for the KCl series, $r = -0.235 \pm 0.072$; for the KBr series, $r = -0.186 \pm 0.158$; and for the $MgSO_4$ series, $r = -0.241 \pm 0.154$.

In the light of the number of observations involved and the magnitude of the probable errors, little significance can be attached to these correlation coefficients. The flours used were quite different in their physical and chemical natures from those used in the study reported by Gortner (1927). The gluten and non-gluten protein ratios in many of the mill streams were undoubtedly quite different from normal wheat flour. This is substantiated by the

observation that the correlation between loaf volume and protein content in the mill-stream flours is strikingly insignificant, whereas in normal flours there is commonly a high positive correlation. It seems probable that when there is no correlation between loaf volume and protein content, there will be little or no correlation between loaf volume and the percentage of protein peptized by any particular salt solution. It should be further noted that in these mill-stream flours not all of the nitrogen can be referable to protein, since undoubtedly portions of germ are present in certain of the mill streams which would introduce non-protein nitrogenous compounds, such as nucleic acid, etc. Strict comparison therefore between data involving normal patent or straight-grade flours and data involving all of the mill streams is not justified.

Summary and Conclusion

A comparative study of the properties of a series of "commercial" and "experimental" flours milled from the same wheats has been made. There was also included in this study a comparative study of the properties of the flours from the seventeen mill streams of the Minnesota State Experimental Flour Mill.

The data presented seem to warrant the following conclusions:

1. The saccharogenic activity of flour milled with the experimental mill does not truly represent the potential activity of commercially milled flour from the same wheat. The flours milled in a commercial mill have from one to four times the saccharogenic activity of flours milled from the same sample of wheat in a small "Experimental Mill."
2. The degree of granulation of flours is an important factor in the consideration of the saccharogenic properties, as is shown by the fact that grinding a sample of flour milled in the commercial mill in a ball mill for twenty hours increased the saccharogenic activity approximately 35 per cent.
3. The basic procedure of the A.A.C.C. experimental baking test, without extended fermentation periods, does not permit detection of flours low in saccharogenic activity (when saccharogenic activity is measured on a flour-water suspension by the Rumsey method) from loaf volume values, as evidenced by the fact that the "commercial" flours and the "experimental" flours, while differing materially in saccharogenic activity did not differ appreciably in loaf volume.

4. In the peptizing action of potassium halide salts on flour proteins, a definite lyotropic effect can be demonstrated. This series is KF>KCl>KBr. The coefficients of variability were calculated for these halide salts, and the KBr series, although showing the highest peptization, showed the lowest variability.

5. The series of "experimental" and "commercial" (patent and straight-grade) flours gave a coefficient of correlation of $r = +0.797 \pm 0.041$ between protein content and loaf volume. A similar correlation on the mill-stream series of flours, all milled from one sample of wheat, was $r = -0.018 \pm 0.163$.

6. The serious objection recently raised against the present definition of a "globulin" is entirely justified. The coefficients of correlation between loaf volume and the fraction peptized from the mill-stream flours by the salts were -0.186 ± 0.158 for the KBr series, -0.235 ± 0.072 for the KCl series, -0.317 ± 0.147 for the KF series and -0.241 ± 0.154 for the $MgSO_4$ series.

7. The correlation coefficients between total protein content and the per cent of protein peptized from the mill stream flours by the various salts varied from +0.839 to +0.877 and the correlation between a variable and the deviation of a dependent variable from its probable value were found to be +0.369 for KBr, +0.555 for KCl, +0.606 for KF and +0.548 for $MgSO_4$ solutions (0.5 N).

These last data indicate that while the fraction of the protein petized by a salt varies with the percentage of protein which is present, nevertheless there is less influence of the original protein content in the KBr series than in the case of the other salts.

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